

Available online at www.sciencedirect.com**ScienceDirect**

Procedia Engineering 118 (2015) 752 – 759

**Procedia
Engineering**www.elsevier.com/locate/procedia

International Conference on Sustainable Design, Engineering and Construction

A Framework for Delivering Targeted Occupancy Interventions to Reduce Energy Usage in Buildings

Aslihan KARATAS^{1*}, Carol C. MENASSA², and Allisandra Stoiko³

¹Postdoctoral Research Fellow, Dept. of Civil and Environmental Engineering, University of Michigan, MI, 48109; email: karatas@umich.edu

²Assistant Professor, Dept. of Civil and Environmental Engineering, University of Michigan, MI, 48109; email: menassa@umich.edu

³Undergraduate Student, Dept. of Civil and Environmental Engineering, University of Michigan, MI, 48109; email: astoiko@umich.edu

Abstract

Policies aimed at reducing building energy use have often resulted in inefficiencies due to their higher costs, requirements to comply with regulations, incentives, and/or sanctions; and neglecting the impact of occupants on building energy use. To overcome these challenges, energy policy measures can be designed and implemented by identifying occupants' behavior that significantly impact building energy use and relevant factors that may lead to sustainable behavior pattern. Therefore, this study presents a conceptual framework that proposes a multi-level intervention strategy that is tailored to varying occupants' characteristics to produce and maintain energy use reduction in buildings over time. The framework is designed in two main steps: (1) identifying the occupants' energy use and behavioral characteristics before and after the exposure of any energy efficiency intervention (e.g., education, persuasion); and (2) delivering targeted occupancy interventions based on occupants' energy use and behavioral characteristics. This framework will assist decision-makers in formulating and designing effective energy policy tools at lower costs to deliver occupancy-focused interventions for reducing building energy use.

© 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of organizing committee of the International Conference on Sustainable Design, Engineering and Construction 2015

Keywords: occupant behavior, energy efficiency, energy policy

* Corresponding author. Tel.: +1-217-721-3621.

E-mail address: karatas@umich.edu

Introduction

The existing building sector in the US accounts for 40 percent of the total energy consumption by the built environment [11]. Moreover, UNEP [31] reported that this sector needs to achieve large-scale energy use reductions cost effectively through efficiency and conservation strategies to alleviate economic, environmental and social problems associated with diminishing natural resources and global warming. To maintain large-scale energy use reduction in existing building sector, energy policy tools can be designed as (i) regulatory tools that are intended to change behavior and often referred to as government command and control systems; (ii) inducement tools that aim to motivate an individual through the promise of a reward or penalty to behave in a certain way without the level of government coercion inherent in regulations; and (iii) capacity tools that are intended to change individual behavior based on providing information in the desired manner [14].

Even if capacity tools are suggested as a starting point for designing energy policy tools [14], they are often designed as either regulatory tools (e.g., occupancy-focused interventions that implement technological solutions such as retrofitting and replacing electrical components) [3,28,36]; or inducement tools (e.g., occupancy-focused interventions that implement reward/penalty systems such as varying energy costs with on- and off-peak consumption) [8,19]. Therefore, this approach leads to several challenges for policy makers such as inefficient results, due to (i) higher costs of policy tools to comply with the regulations and incentives [14,37]; and (ii) ignoring the significant impact of occupants and their energy use characteristics in buildings [6,21,30]. To address these challenges in the development of energy policy tools, this study develops a conceptual framework that proposes a multi-level intervention strategy targeted towards the diverse human characteristics to produce and maintain energy use reduction in buildings over time. This framework assists decision-makers in designing cost-effective energy policy tools to deliver effective energy efficiency occupancy-focused interventions.

Objectives

The aim of this paper is to present a conceptual framework for assisting policy makers in designing effective energy policy tools at lower costs. This framework proposes multi-level building energy use intervention strategies focused on targeting occupants' energy use characteristics. To accomplish this, the study is designed in three main stages: (1) reviewing energy efficiency intervention strategies; (2) identifying the role of occupants' characteristics in building energy use; and (3) developing a conceptual framework that links the occupants energy use characteristics to the multi-level energy efficiency intervention strategies, and accordingly energy policy tools.

Energy Efficiency Intervention Strategies Review

To engage occupants in reducing energy use in buildings, several studies in literature analyzed four main levels of interventions: education, persuasion, penalties, and technology. A detailed description of each intervention level is provided below.

Education consists of presenting informative messages to invoke voluntary behavior change. Several research studies were conducted of education methods to reduce energy use in buildings by information distribution outlets (e.g., posters, videos, brochures) to convey information to influence consumers [2,16,22]; interactive programs (e.g., site-specific video programs) with more personalized approaches to information delivery [12,23]; feedback methodology that is based on presenting information comparing current energy use with historical use that provides consumers with personalized evaluation and a means to monitor progress [10,32]; and peer-comparison by allowing occupants to acknowledge their energy consumption compared to their peers [17]. Among these education methods, studies showed that information distribution of energy consumption facts and reduction guidelines don not appear to effectively influence consumers. While information distribution is a widely tested form of education, it appears to be largely ineffective on its own [2,16,22]. When it comes to interactive programs, studies highlighted that extended interactive programs may yield a better results compared to the short-term ones [12,23]. Finally, feedback and peer-comparison appear to be the most effective education methods to single-handedly influence consumers' energy consumption [10,17,32].

Persuasion involves providing rewards to encourage a favorable behavior. Several studies have been conducted regarding incentives such as monetary incentives [4,15], and pledging campaigns as incentives to encourage sustainable energy conservation behavior [7,35]. Monetary incentives appear to be effective, particularly persuasion

with long-running application and low monetary incentives may be most effective in changing habits. Pledging also appears effective to encourage behavior. Studies showed that consumers receiving complementary products (e.g., t-shirt, travel mug) were more likely to participate in the program. A pledge campaign with free merchandise could be incorporated at a relatively low cost.

Penalties consist of negative consequences that discourage an unfavorable behavior. Several studies have focused on the influence of penalties in the context of energy conservation. These studies considered dynamic building control, altering energy costs with on- and off-peak consumption, and observed that increased price of on-peak electricity reduced consumption of energy during that period [18,19].

Technology consists of tools and systems that solve problems without continued human influence. Previous studies and statistics demonstrated the most effective forms of technology for reducing overall energy use. For example, Wong, et al. [36] and Ruzelli [28] suggested that careful building design, including building automation systems, can dramatically reduce energy use. These studies assert that light roofs can use 40% less energy for cooling, that albedo roof coatings can result in an HVAC energy savings of 8.7% to 27.5%, and that rooftop gardens can realize 0.6-14.5% annual energy savings.

The Role of Occupants Characteristics in Building Energy Use

Policies that aim to encourage occupancy engagement in energy reduction strategies should simultaneously examine effectiveness of interventions and possible determinants of behavior [1,29]. Therefore, the proposed framework in this study adopted an analogy where intervention strategies can be regarded as advertisements enticing the building occupants to adopt certain energy use characteristics. This analogy was investigated by conducting a comprehensive literature review in the consumer and social marketing field [20,24,25,27]. These studies highlighted that consumers' (i.e., occupants in this research) attention and comprehension processes to brand information (i.e., intervention strategy information in this research) are strongly influenced by their motivation/opportunity/ability (MOA) characteristics to process significant information in their environment.

Motivation (M) refers to the desire to process brand information in an advertisement [13,26,29,38]. In this presented framework, Motivation Level of an occupant measures a particular occupant's perceived personal relevance and the level of involvement with the information (e.g., external stimuli) presented in the energy intervention strategy. Moreover, Ability (A) has been defined as consumers' skills or proficiencies in interpreting brand information in an advertisement [9,20,27]. In this framework, Ability Level of an occupant measures a given occupant's proficiencies in interpreting energy use knowledge. This ability is largely dependent on the occupant's prior knowledge about energy use and conservation acquired through experience (e.g., asking occupants to turn light off before leaving their offices). Finally, Opportunity (O) Level has been defined as an extent to which circumstances evidenced during advertisement exposure are favorable for brand processing [13,20,27]. In this framework, Opportunity (O) Level of an occupant represents an important pre-condition for both motivation (M) and ability (A), and is directly related to the immediate environment of the occupants and how that affects the availability, accessibility and time allocated for comprehension of the energy use knowledge.

A Framework for Delivering Targeted Occupancy Interventions to Reduce Energy Use in Buildings

When designing policy measures that are aimed at reducing energy use, it is important to identify occupants' behaviors that significantly contribute to environmental problems, and then, identify the factors that make sustainable behavioral patterns attractive [33]. Therefore, the framework in this study proposes a multi-level intervention strategy targeted towards the diverse human characteristics to sustain energy use reduction in buildings over time. To achieve this, the presented framework for designing effective energy policy tools includes two main steps. The first step is quantitatively measuring and clustering occupants' pre-exposure MOA level and energy use profiles (i.e. occupants' situational characteristics prior to any intervention) and post-exposure MOA levels to determine effectiveness of intervention level (e.g., education, persuasion or combination) to use for a given energy reduction strategy (e.g., encouraging occupants to turn office lights off when not in use). In this step, occupants' pre-existing MOA levels are classified into main target clusters relative to their potential to process energy use knowledge. Azar and Menassa [5] identified the different occupants' energy use characteristics as 'High Energy Consumers' that represents occupants that over-consume energy; 'Medium Energy Consumers' that represents occupants making minimal efforts towards energy savings form the category; and 'Low Energy Consumers' that

represents occupants that use energy efficiently. Based on these identified characteristics, this study classified occupants' MOA levels into three categories: "prone to react" (i.e., occupants who are willing to adopt energy reduction strategies immediately), "unable to react" (i.e., occupants who are willing to adopt energy reduction strategies immediately but do not have the necessary knowledge and tools to do that), and "resistant to react" (i.e., occupants who are unwilling to adopt energy reduction strategies regardless of whether they have the necessary knowledge and tools or not), as shown in Figure 1.

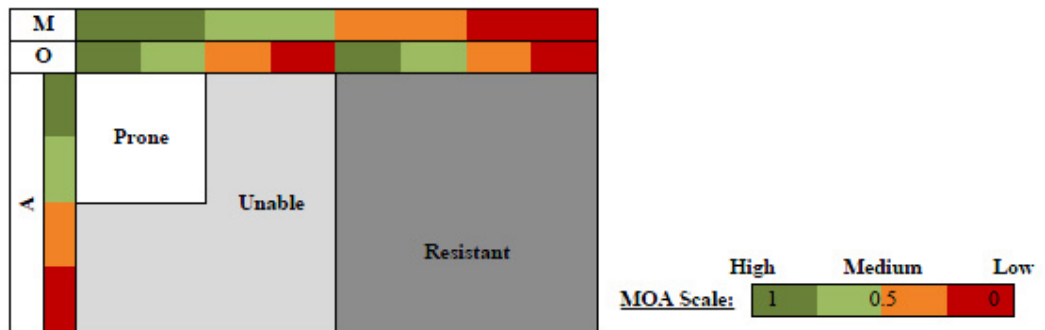


Figure 1: MOA Levels of Occupants

The second step is linking occupants MOA levels to the multi-level energy efficiency intervention strategies, and accordingly energy policy tool types (i.e. Capacity tools, Inducement Tools, and Regulation Tools), as shown in Table 1. Four energy-efficiency intervention strategies (i.e. Education, Persuasion, Penalties, and Technology) were classified into: the expected benefits/costs (e.g., sanctions, penalties and legal consequences to behave in a certain way without the level of government coercion inherent in regulations for non-compliance energy use behavior), the expected occupant reactions of the target to each intervention (e.g., un-coerced free choice behavior that refers to the change of energy use behavior voluntarily), the time to achieve expected benefits (e.g., direct and timely exchange for desired energy use behavior that refers to direct reinforcement by the government command and control systems), and finally the perceived link to the occupant MOA levels (e.g., "prone to react" that refers to the occupant who has self-interest and consistent with societal goals, and is willing to adopt energy reduction strategies without additional reinforcement).

Table 1: Multi-Level Building Energy Use Intervention Strategies

| Energy Policy Tools | Interventions | Expected Benefits/Costs | Occupant Reactions | Time to Achieve Benefits | Occupant MOA: Characteristics |
|---------------------|--|---|--|---|--|
| Capacity Tools | EDUCATION: attempts to teach and create awareness about benefits of a particular behavior. | No explicit reward/penalty | Un-coerced free choice behavior. <i>Voluntary compliance</i> | Promise of future potential payback. Unable to reinforce directly | MOA = Prone to React Strong self-interest and consistent with societal goals. Merely uninformed occupant. No additional reinforcement necessary. |
| | PERSUASION: offers reinforcing consequences, invite voluntary exchange. | Positive reward/punishment delivered when exchange transaction is completed | Un-coerced free choice behavior. <i>Voluntary exchange</i> (self-monitoring – self-sanctioning) | Promise of future potential payback. Unable to reinforce directly. Expects free market exchange | MOA = Unable to Slightly Resistant to React Strong self-interest but insufficiently consistent with societal goals and reinforcement in self-interest. |
| Inducement Tools | PENALTIES: prescribes a body of rules of action/conduct. | Sanctions, penalties and legal consequences for non-compliance | Coerced behavior. <i>Non-voluntary compliance</i> | Direct and timely exchange for desired behavior. Direct Reinforcement | MOA = Resistant to React Existing self-interest cannot be overcome with additional rewards through exchange. |
| Regulation Tools | TECHNOLOGY: control behavior change and referred to governmental authority and legitimacy | Law or other costly regulations without requiring a promise of a positive incentive | Coerced behavior. <i>Non-voluntary compliance</i> | Direct and timely exchange for desired behavior. Direct Reinforcement | MOA = Resistant to React Existing self-interest cannot be overcome with laws which may result in shirking and moral hazards. |
| | | | | | |

Discussion

For decision-makers (e.g., researchers and policy makers), it is important to systematically evaluate the effects of interventions and their impacts' on occupants' behavior [1,29]. To achieve this, the conceptual framework presented in Table 1 represents energy policy tools and their related multi-level building energy use intervention strategies. Using this framework, effectiveness of these intervention strategies can be examined based on occupancy related actions (e.g., After-hours equipment use; Occupied and Unoccupied Hours; Cooling and Heating Temperature Set points; After-hours lighting use).

Moreover, each intervention strategy can be evaluated using four criteria: *attributes* (e.g., offers occupant alternative to changing heating set point), *consequences* (e.g., I will have to bring an extra jacket, I will be rewarded for turning lights off with a gift card to my favorite store), and *time and cost of implementing* the intervention (e.g., education is cheapest as it does not require exchange of rewards or penalties for achieving required change and can be implemented immediately). This set of criteria will guide decision makers in the selection of intervention strategies by providing them with research-based evidence of its effectiveness to achieve the required energy reductions given the occupants' MOA characteristics [34]. Accordingly, decision makers can (i) determine what

type of building energy use intervention strategies to be selected for achieving the required energy reductions at lower costs based on the occupants' energy use characteristics; and (ii) how to design cost-effective energy policy tools to deliver multi-level energy efficiency occupancy-focused interventions that promote actions for improving sustainable behavior pattern. Currently the authors are testing the implementation of this conceptual framework in real case study buildings. Data from the occupants of an actual building and their energy consumption are being collected from several buildings at the University of Michigan. Then, the effectiveness of intervention strategies on different occupants' characteristics will be investigated to validate the proposed framework.

Conclusion

This paper aims to present a conceptual framework that provides a linkage between occupancy-focused intervention strategies and occupant energy use characteristics to deliver multi-level intervention strategies, and accordingly develop effective energy policy tools. To achieve this, a comprehensive literature review was conducted on occupancy-focused intervention strategies to reduce energy use. We further investigated energy use characteristics of occupants by identifying the analogy between MOA characteristics of people to process brand information in their environment, and MOA levels where occupancy-focused intervention strategies can be regarded as advertisements enticing the building occupants to adopt certain energy use characteristics. Then, the proposed framework was presented that organizes multi-level intervention strategies (i.e. Education, Persuasion, Penalties, and Technology) under each type of energy policy tools (i.e. Capacity tools, Inducement Tools, and Regulation Tools), and establishes a link to the occupants' MOA levels. This framework will assist researchers and policy makers in designing and implementing effective energy policy tools to deliver occupancy-focused intervention programs cost-effectively that increase the attractiveness of pro-environmental behavior and encourage a more sustainable behavior pattern.

Acknowledgement

The authors would like to acknowledge the financial support for this research received from the US National Science Foundation (NSF) CBET 1407908 and 1349921. Any opinions and findings in this paper are those of the authors and do not necessarily represent those of NSF.

REFERENCES

- [1] W. Abrahamse, L. Steg, C. Vlek, T. Rothengatter, A review of intervention studies aimed at household energy conservation, *Journal of environmental psychology* 25 (3) (2005) 273-291.
- [2] M. Agha-Hosseini, R. Tetlow, M. Hadi, S. El-Jouzi, A. Elmualim, J. Ellis, M. Williams, Providing persuasive feedback through interactive posters to motivate energy-saving behaviours, *Intelligent Buildings International*, (ahead-of-print) (2014) 1-20.
- [3] J.M. Akridge, High-albedo roof coatings- impact on energy consumption, (1998).
- [4] M.A. Alahmad, P.G. Wheeler, A. Schwer, J. Eiden, A. Brumbaugh, A comparative study of three feedback devices for residential real-time energy monitoring, *Industrial Electronics, IEEE Transactions on* 59 (4) (2012) 2002-2013.
- [5] E. Azar, C. Menassa, An agent-based approach to model the effect of occupants' energy use characteristics in commercial buildings, *American Society of Civil Engineers (ASCE)*, (2011) 536-543.
- [6] E. Azar, C.C. Menassa, A comprehensive analysis of the impact of occupancy parameters in energy simulation of office buildings, *Energy and Buildings* 55 (2012) 841-853.
- [7] T.E. Boyce, E.S. Geller, Encouraging College Students to Support Pro-Environment Behavior Effects of Direct Versus Indirect Rewards, *Environment and Behavior* 33 (1) (2001) 107-125.
- [8] J.E. Braun, Reducing energy costs and peak electrical demand through optimal control of building thermal storage, *ASHRAE transactions* 96 (2) (1990) 876-888.
- [9] R.L. Celsi, J.C. Olson, The role of involvement in attention and comprehension processes, *Journal of Consumer research*, (1988) 210-224.
- [10] P. Dolan, R. Metcalfe, Neighbors, knowledge, and nuggets: two natural field experiments on the role of incentives on energy conservation, (2013).
- [11] U.E.I.A. EIA, How much energy is consumed in residential and commercial buildings in the United States?, Vol. 2014, 2014.

- [12] E.S. Geller, Evaluating energy conservation programs: Is verbal report enough?, *Journal of Consumer research*, (1981) 331-335.
- [13] R. Govindaraju, A.F. Hadining, D.R. Chandra, Physicians' Adoption of Electronic Medical Records: Model Development Using Ability–Motivation–Opportunity Framework, *Information and Communication Technology*, Springer, 2013, pp. 41-49.
- [14] L.C. Hand, Public Policy Design and Assumptions About Human Behavior, Western Political Science Association's Annual Conference, <http://wpsa.research.pdx.edu/meet/2012/handlaura.pdf>, 2012.
- [15] M.J. Handgraaf, M.A. Van Lidth de Jeude, K.C. Appelt, Public praise vs. private pay: Effects of rewards on energy conservation in the workplace, *Ecological Economics* 86 (2013) 86-92.
- [16] S.C. Hayes, J.D. Cone, REDUCING RESIDENTIAL ELECTRICAL ENERGY USE: PAYMENTS, INFORMATION, AND FEEDBACK1, *Journal of Applied Behavior Analysis* 10 (3) (1977) 425-435.
- [17] H.A. He, S. Greenberg, E.M. Huang, One size does not fit all: applying the transtheoretical model to energy feedback technology design, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 2010, pp. 927-936.
- [18] T.A. Heberlein, G.K. Warriner, The influence of price and attitude on shifting residential electricity consumption from on-to off-peak periods, *Journal of Economic Psychology* 4 (1) (1983) 107-130.
- [19] M. Kouveletsou, N. Sakkas, S. Garvin, M. Batic, D. Reccardo, R. Sterling, Simulating energy use and energy pricing in buildings: The case of electricity, *Energy and Buildings* 54 (2012) 96-104.
- [20] D.J. MacInnis, C. Moorman, B.J. Jaworski, Enhancing and measuring consumers' motivation, opportunity, and ability to process brand information from ads, *The Journal of Marketing*, (1991) 32-53.
- [21] A. Mahdavi, C. Pröglhof, Toward empirically-based models of people's presence and actions in buildings, *Proceedings of building simulation*, Vol. 9, 2009, pp. 537-544.
- [22] R.W. Marans, J.Y. Edelstein, The human dimension of energy conservation and sustainability: a case study of the University of Michigan's energy conservation program, *International Journal of Sustainability in Higher Education* 11 (1) (2010) 6-18.
- [23] A.H. McMakin, E.L. Malone, R.E. Lundgren, Motivating residents to conserve energy without financial incentives, *Environment and Behavior* 34 (6) (2002) 848-863.
- [24] C. Moorman, The effects of stimulus and consumer characteristics on the utilization of nutrition information, *Journal of Consumer research*, (1990) 362-374.
- [25] M.J. Polonsky, W. Binney, J. Hall, Developing Better Public Policy to Motivate Responsible Environmental Behavior—An Examination of Managers' Attitudes and Perceptions Towards Controlling Introduced Species, *Journal of nonprofit & public sector marketing* 12 (1) (2004) 93-107.
- [26] M.L. Richins, P.H. Bloch, After the new wears off: the temporal context of product involvement, *Journal of Consumer research*, (1986) 280-285.
- [27] M.L. Rothschild, Carrots, sticks, and promises: a conceptual framework for the management of public health and social issue behaviors, *The Journal of Marketing*, (1999) 24-37.
- [28] A. Ruzelli, *Proceedings of the 2nd ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Building*, ACM, Zurich, Switzerland, 2010, p. 93.
- [29] L. Steg, C. Vlek, Encouraging pro-environmental behaviour: An integrative review and research agenda, *Journal of environmental psychology* 29 (3) (2009) 309-317.
- [30] J. Tanimoto, A. Hagishima, TOTAL UTILITY DEMAND PREDICTION BASED ON PROBABILISTICALLY GENERATED BEHAVIOURAL SCHEDULES OF ACTUAL INHABITANTS, (2009).
- [31] U.N.E.P. UNEP, Sustainable Buildings and Climate Initiative Promoting Policies and Practices for Sustainability, Vol. 2014, 2014.
- [32] J.H. Van Houwelingen, W.F. Van Raaij, The effect of goal-setting and daily electronic feedback on in-home energy use, *Journal of Consumer research*, (1989) 98-105.
- [33] C. Von Borgstede, M. Andersson, F. Johnsson, Public attitudes to climate change and carbon mitigation—Implications for energy-associated behaviours, *Energy Policy* 57 (2013) 182-193.
- [34] M. Wensing, M. Bosch, R. Grol, Developing and selecting interventions for translating knowledge to action, *Canadian Medical Association Journal* 182 (2) (2010) E85-E88.
- [35] D.D. Whitsett, H.C. Justus, E. Steiner, K. Duffy, Persistence of Energy Efficiency Behaviors over Time: Evidence from a Community-Based Program, (2013).
- [36] N.H. Wong, D. Cheong, H. Yan, J. Soh, C. Ong, A. Sia, The effects of rooftop garden on energy consumption of a commercial building in Singapore, *Energy and Buildings* 35 (4) (2003) 353-364.
- [37] J. Yudelson, *Greening existing buildings*, McGraw-Hill New York, 2010.

- [38] J.L. Zaichkowsky, Measuring the involvement construct, *Journal of Consumer research*, (1985) 341-352.